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ANTHRACNOSE OF COTTON.*

(Plate IV.)

By E. A. SOUTHWORTH.

This disease, like others of the same name, is exceedingly destructive to the plants which it attacks and is caused by a fungus resembling the Glœosporiums. The presence of dark-colored setæ among the spores and basidia separates it from the genus *Glœosporium* and makes it a *Colletotrichium*, but the general character of the fungus, so far as its effect on the host is concerned, is very similar to that of the Glœosporiums, well known as Anthracnose of the grape and raspberry. In the cotton fungus the setæ do not at first develop in any numbers, but become very numerous as the fungus grows older.

When the fungus was first brought to our notice, some immature specimens were sent to Mr. Ellis, who afterwards sent them to Mr. Cooke; both agreed that they were identical with *Glœosporium carpigenum*, Ck. & Hk., and the fungus was distributed in Ellis's North American Fungi under this name. Through the kindness of Professor Harkness I have recently been enabled to compare it with type specimens of *G. carpigenum*, and find it quite distinct from this fungus. *G. carpigenum* is a true *Glœosporium* with no setæ and the fruit borne in isolated pustules. The spores are also much smaller than those of the cotton fungus. These characters, as will be seen further on, separate the latter from *Glœosporium carpigenum* and the possession of setæ places it in the genus *Colletotrichium.* There seems to be no record of any specific name ever having been given it and I will call it *Colletotrichium gossypii.*†

EXTERNAL APPEARANCE AND EFFECTS ON THE BOLL.

According to Mr. Atkinson, who has observed the disease in the field, the fungus attacks all parts of the plant. It has been sent to us, however, only on the boll, and this description must therefore be limited.

So far as can be judged from specimens that have been picked from one to five days and sent through the mails, the external appearance and progress of the disease on the boll is as follows:

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* Since this article was prepared, Professor Atkinson read a paper on the same subject before the Association of American Agricultural Experiment Stations at Champaign, Ill. The work in both cases was entirely independent, except where I have cited Professor Atkinson's authority in regard to the parts of the host plant attacked.—E. A. S.

† *Colletotrichium gossypii*, n. s. On cultivated cotton, may occur on any part of the plant, especially injurious to bolls. Sori orbicular, dark colored, or covered with a pink powder. Acervuli erumpent, distinct only when young. Spores irregularly oblong, usually with a light spot in the center, often acute at one end, colorless singly, flesh-colored in mass, borne on short basidia or long setæ. Basidia colorless varying in length, at least longer than the mature spore, very rarely branched, borne on a stroma of varying thickness, $11\text{–}28 \times 5\mu$. Setæ occurring singly or in tufts, more abundant in older specimens, dark brown at base, but nearly colorless at the apex, septate, often irregular in outline, straight or flexuose, rarely branching, often bearing spores. Mycelium septate, intra and intercellular, usually colorless, producing secondary dark colored spores, especially when it has simply the form of a germ tube. Stroma of varying thickness, often penetrating the plant tissues for some distance, becoming dark colored with age or where setæ are borne.

One or more dark colored spots make their appearance on the green capsule. These increase in size and usually become covered with a flesh-colored powder for a short time. This is likely to disappear later leaving a poorly defined spot from which a blackish discoloration, often showing little spots of the pink powder on its surface, extends over the boll. The black discoloration may reach a considerable extent before the spot becomes pink at all, and judging from the appearance of some of the bolls it would seem as if the black color sometimes appears independently, without the pink spots. The growth of the capsule ceases wherever the discoloration extends; this causes the segments to crack apart through the diseased areas, leaving the half-ripe cotton exposed to the rain and dew as well as to the attacks of numerous insects. The capsule itself loses its power of resisting moisture and often becomes water-soaked and covered by saprophytic fungi. The saprophytic fungi, as well as the fungus causing the disease, often penetrate the cotton mass itself and the exposed portion becomes covered with a pinkish powder or with the white filaments and fruit of the saprophytes. As might be expected under these untoward circumstances, the cotton, and often the seeds as well, decays very quickly, especially if wet weather follows and if the bolls are attacked when young. If, however, they do not become diseased until they are nearly ready to burst open, and the weather remains dry, they may not be materially injured.

BOTANICAL CHARACTERS.

The vegetative portion of the fungus is branching and septate (Fig. 6), usually colorless, but sometimes showing a little darkening of the walls, of varying diameter, but usually about 5 μ. The mycelium penetrates the cells, often showing a constriction where it passes through the walls, with a slight enlargement on one or both sides (Fig. 5.). Frequently a hypha runs along in contact with the wall for some way before it pushes through. The mycelium is exceedingly abundant in the tissues, and sometimes appears to nearly fill the cells. In consequence of its presence the cell contents become disorganized and the cell walls frequently collapse, especially near the surface, where a section through the diseased tissue shows no cavities remaining. The chlorophyll is at first resolved into bright green globular masses, but later all the green color disappears, leaving only a small quantity of disorganized brownish material in the cells.

Anywhere in its course the vegetative mycelium may send off branches which push out to the surface and bear spores at their free ends. A quantity of these are generally sent off close together and become so matted at the surface of the boll that a stroma is formed from which spring the ends of the spore-bearing branches or basidia. This stroma varies very much as regards quantity; it may be a scarcely perceptible layer, or it may extend for some distance above the surface and penetrate between the cells for three or more layers (Fig. 3), completely surrounding the discolored cell fragments that remain, probably because the fungus is not able to absorb them. In older specimens the fruit is not borne in distinct pustules, but the epidermis seems to be broken up into flakes and the basidia are borne uniformly or in tufts on the fruiting surface. In the course of from two days to a week after the first basidia and spores are formed the dark brown setæ may be formed among them. They grow out from somewhat enlarged darker cells in the stroma, and are bluntly rounded at first, but become more acute as they grow older. They are frequently enlarged or present other irregularities somewhere along their course, especially near the tip (Fig. 1 *a*). The bases are a very dark brown, but the tips are usually nearly colorless. Under some conditions, especially in a moist atmosphere, the setæ may bear spores at their tips. These spores seem to be somewhat smaller than those borne on the regular basidia, but in artificial cultures the two kinds are indistinguishable. At first the setæ are few, but they increase in number with the age of the fungus, and in some sections the conclusion that the basidia themselves are being transformed into setæ is almost irresistible. In older specimens the setæ appear in large tufts and sometimes branch. It is not infrequently the case that one seta arises from the lower end of another; a beginning of this may be seen in Fig. 1. The amount of stroma is also seen to increase with age, especially beneath the setæ, where it becomes very dark colored. In old specimens the setæ are borne considerably above the basidia, so that the latter line the cavities between them (Fig. 1). The tufts of setæ may even have the appearance of being pushed up and out of the way by the basidia and spores behind them.

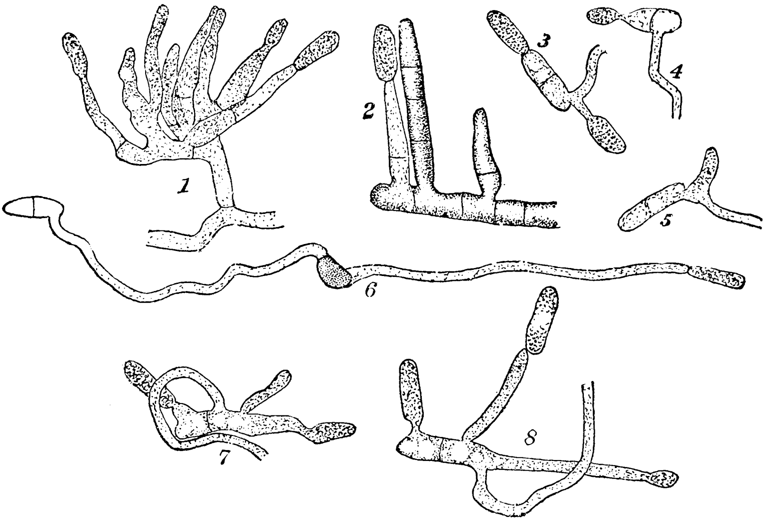
The spores are oblong, and usually have a vacuole in the center. Viewed separately under the microscope they are colorless, but in masses they form a salmon-pink powder which gives the color to the spots as already described. They are successively abscised from colorless basidia, which vary greatly in length and may branch when kept excessively moist (Figs. 4–7). Usually the connection between the spore and the basidium becomes smaller until the spore is cut off; but there are cases where the spore falls from the end of the basidium when the septum separating them is half as wide as the basidium itself, which appears truncate after the spore has fallen. The setæ which have borne spores also often have a truncate appearance.

The fungus retains its vitality under very adverse circumstances. Some specimens of diseased bolls were allowed to lie in the heated air of the laboratory for a month or more. The pink spore powder was then entirely washed from the surface, a piece cut out and soaked, and placed under a bell glass. In three days the surface again showed small masses of pink spores that had been produced since the fungus was put under the bell glass.

An attempt was made to grow this fungus in a decoction of hollyhock agar-agar. This was only a partial success, for while spores and setæ were produced the fungus was evidently in an unfavorable medium and was short lived. However, some very important results were obtained.

In forty three hours from the time of sowing, a distinct mycelium had been formed which bore numerous basidia at right angles to its branches and these were already producing spores (Fig. 7 b). Along with these spore-producing branches were others which differed from the basidia and ordinary mycelial branches in being devoid of visible granular contents, and on close inspection seemed to be a trifle darker colored and thicker walled. They sometimes had a septum near the base and were shaped like setæ. Twenty four hours later there were well developed setæ on the same mycelium that bore the basidia and spores. As the mycelium grew older more setæ made their appearance; but in the moist environment in which it was necessary to keep the artificial substratum nearly all of them bore spores and were even more irregular in appearance than they are in nature.

After the setæ begin to form it is difficult to find basidia and setæ close together. The parts of the mycelium that bear setæ bear nothing else. Septa are often produced in the mycelium at each side of the bases of the setæ and the cell thus formed sometimes grows larger and darker colored than the remainder of the filament, while the threads which bear setæ are often coarser and darker colored throughout. This may explain the dark colored cells at the bases of the tufts of setæ as they occur in nature.



1. Tuft of basidia, with young spores rising from a single thread, showing mode of formation of fruiting surface.
2. Basidium and seta springing from the same mycelial thread.
3, 4, and 5. Spores twenty-four hours in water, showing spores produced by budding.
6. Germinating spore, with germ-tube and secondary spore, which in turn has sent out a germ-tube bearing a spore at the end.
7 and 8. Spores forty-eight hours in water.

Spores were also sown in a decoction of cotton bolls in agar-agar. In this the fungus grew more luxuriantly and rapidly, but was much slower in producing setæ, and when these were first discovered, nearly a week after they were sown, they were already bearing spores. For the first few days only colorless basidia could be found. When a spore was produced on this mycelium it was cut off from the end of the basidium and another formed on the same place, pushing the former one aside. This may occur until there is a large collection of spores at the end of the basidium, the spores that are pushed aside lying adjacent to the second one along their entire length (Fig. 7).

When spores are sown in pure water they exhibit a phenomenon which can scarcely be called anything but budding (Figs. 1–5, 7, 8, p. 103). They become once septate, and while one division sends out a germ tube the other gives rise to another spore, separated from the first only by a short neck. The germ tube also frequently sends out a spore just beyond the point where it leaves the spore (Figs. 3, 5, p. 103). By the time a spore has been two days in water the cell that at first gave rise to the germ tube may also have produced several spores, either by budding or upon a short thread.

Secondary dark colored spores (Fig. 6, p. 103) are also often produced in great numbers both when the spores are germinated in water and in nutritive media. In the latter they are sometimes so abundant as to give the mycelium a dark color when seen by the naked eye. These bodies are usually regular at first, but become very irregularly lobed and even reproduce themselves by constriction. They also give rise to other mycelial filaments. I do not understand their special function.

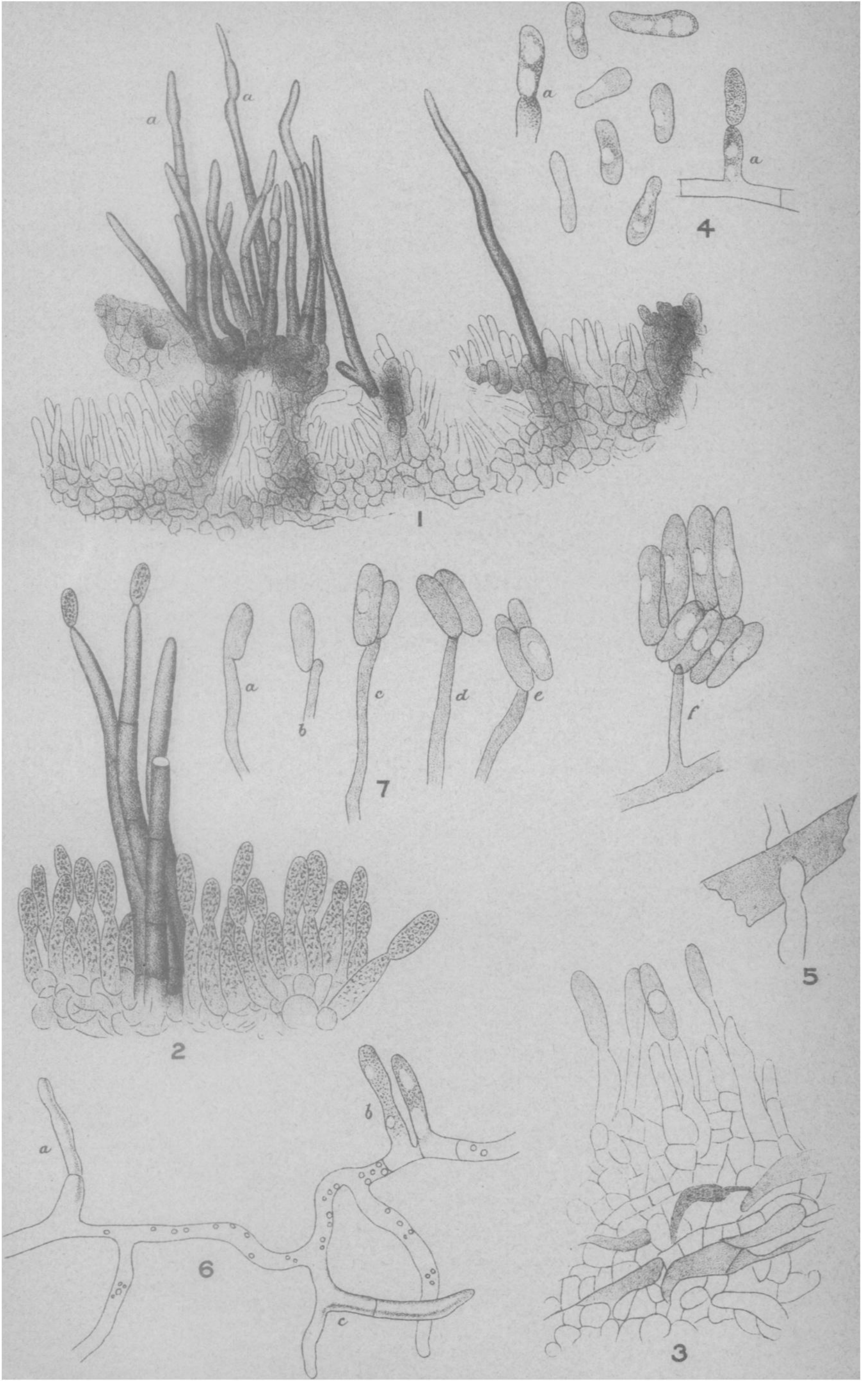
GENERAL NOTES.

Just how long the disease has existed or has been a source of trouble to cotton growers can not well be ascertained; but those who have written us concerning it speak of it as new, and it is safe to say that it has greatly increased in destructiveness during the last three years and has now become a source of danger to the cotton industry.

It was first brought to our attention in the summer of 1888 by a letter from a cotton grower in Louisiana. Last year, we received no complaints in regard to it, but during the last few months repeated inquiries have been sent in, and in two cases, one from Alabama and one from Louisiana, it is reported as destroying 75 per cent. of the crop. In general, however, it seems to destroy from 10 to 25 per cent. The disease is evidently not a new one, as a specimen dating back five or six years has been found in the Department herbarium. In this case, however, only a saprophytic fungus which had nearly overgrown the true cause of the trouble was named on the label.

It seems to have appeared at first on the improved varieties and is worse in wet seasons. That it is widespread is evidenced by the fact

JOURNAL OF MYCOLOGY, U. S. DEPARTMENT OF AGRICULTURE. PLATE IV.



E.A.S. del. SOUTHWORTH ON ANTHRACNOSE OF COTTON.

Colletotrichium gossypii, n. s.

that it has been reported to us from Arkansas, Louisiana, Indian Territory, and Mississippi.

From the nature of the disease there is every reason to fear that it will be very difficult to prevent by fungicides. Anthracnose of the grape is more obstinate than black-rot, and no well defined, certain remedy is yet known for it. The treatment of anthracnose of beans and melons has been attempted on a small scale and has failed completely. The hollyhock disease has been only partially prevented by the use of fungicides that would have succeeded perfectly with black-rot of grapes or leaf-blight of pear. In some of these cases, however, a partial success has been attained and the indications are that the proper use of Bordeaux mixture may finally conquer even this type of fungus.

The vitality of the fungus as shown by its reviving after drying, and the power of the spores to reproduce themselves, are very sure indications of one mode of preventive treatment, viz, the removal from the field of all diseased bolls as soon as possible. A worthless boll will be likely to produce fresh spores with every rain, and if left over winter in the field will probably prove a source of infection the following season, for each spore is capable of infecting a fresh boll. One infection experiment was made on three healthy bolls. The spores were inserted in a cut and the fungus was produced in great quantities all around the cut. The value of this experimment was lessened by the fact that the fungus also appeared on one of the check bolls and that all were taken from a field in which the disease was present. The fact, however, that on the infected bolls the fungus was confined to the vicinity of the cuts is evidence that it was caused by the inserted spores.

Plans are being made to test the value of fungicides in checking this disease during the next cotton-growing season.

EXPLANATION OF PLATE.

Colletotrichium gossypii, n. s.

Fig. 1. Section through old fruiting layer, showing the setæ borne on dark-colored cells, above the level of the basidia; *a a*, enlargements of setæ near the end. X 360.

Fig. 2. Section through younger portion of fruiting layer. Two setæ bearing spores. X 600.

Fig. 3. Section showing stroma mixed with tissues of the boll. X 800.

Fig. 4. Spores; *a a*, borne on basidia. X 600.

Fig. 5. Filiament of mycelium passing through cell wall. X 800.

Fig. 6. Portion of artificial mycelium bearing setæ at *a* and *c*, and at *b* basidium with immature spore. X 600.

Fig. 7. Different stages in the formation of spores in artificial culture. X 600.